General

1. INTRODUCTION

Dust filters were the first secondary emission reduction measure in the cement industry. The motivation for dedusting of exhaust gas and vent air are:

- Compliance with environmental regulations
- Reduction of product loss
- Protection of employees and equipment from harmful dust impacts (irritation plugging, erosion)

This paper is focused on the dedusting of kiln/raw mill exhaust gas and clinker cooler vent air. They are the largest dust filters of the entire clinker production line. Because they have to provide both very high reliability and efficiency under extremely severe conditions those filters have to fulfill the most difficult task among all cement plant dedusting equipment. The basic working principles of the presented filters are also valid for other applications.

2. PRESENT STATE OF CEMENT KILN EMISSION

According to the very much varying dust emission limits in countries where cement plants are operated and the development in the dedusting technology, the average dust emission from cement kilns varies between 10 and 500 mg/Nm^3 dry. Only a few exceptions are above 1000 mg/Nm^3.

3. PRESENT LEGAL SITUATION

Dust was one of the first stack emissions that were regulated and is today still the only emission limit for some plants. The reduction efficiency required is much higher compared to other emissions like SO_2 or NO_x. The dedusting efficiency of modern dust filters is about 99.999% compared to only 95% of very good SO_2 filters.

In Europe, emission limits are expressed as mass of particulates per gas volume: mg/Nm^3 (N: 273 K and 101325 Pa). Usually the gas volume is calculated on dry base. In some countries the gas volume is referred to a certain oxygen concentration, mostly 10% O_2.

Emission Limits

Nm^3_{dry}= m^3 at 273 K, 101300 Pa and 0% water

Europe:	20 - <u>50</u> - 500 mg/Nm^3
Germany:	50 mg/Nm^3 $_{\text{dry at 10\% O2}}$

In the United States of America not all plants do have a dust emission standard. But all of them do have an opacity limit which is to some degree correlated to the dust emission.

USA (e.g.):	0.3 lb/$t_{\text{feed, dry}}$	ca. 80 mg/Nm$^3_{\text{2\%O2, wet}}$
	0.05 - 0.08 gr/dscf	ca. 115 - 180 mg/Nm^{3dry}
	0.015 gr/acf	ca. 60 mg/Nm$^3_{\text{2\% O2, wet}}$
	5.5 lb/hr	ca. 15 mg/Nm$^3_{\text{2\% O2, wet}}$

Some US plants also have to comply with PM10 limits. PM10 stands for particulates smaller than 10 µm. Particulates smaller 10 µm are small enough to enter and mechanically damage the lungs. To express the limits the same units as discussed above are used.

USA PM10 (e.g.):	0.016 gr/dscf	ca. 37 $mg/Nm^3_{2\%\ O2,\ wet}$
	4.7 lb/h	ca. 13 $mg/Nm^3_{2\%\ O2,\ wet}$
	0.015 gr/acf	ca. 60 $mg/Nm^3_{2\%\ O2,\ wet\ t}$

US plants burning hazardous waste are regulated under BIF (Burners and Industrial Furnaces). Other plants do have a state permit defining certain parameters like NO_x, SO_2 CO, particulates (dust) and THC emission. The limits for these emissions are called emission standards. This standards are individually defined for each plant and usually represent the operating situation under certain conditions. Therefore, the US standards are different from the emission limits in Europe where emission limits are valid for a whole state or country.

For comparison reasons all emission limits/standards are indicated in mg/Nm^3. The emission standards in the USA are usually not using mg/Nm^3 but ppm, $lb/t_{dry\ feed}$gr/dscf, lb/1000 lb_{gas}, b/hr, etc. To convert them into mg/Nm^3 certain assumptions were necessary.

All the above explained emission limits do include definitions how and when the compliance tests have to be carried out. It is, e.g., very important whether the emission has to be measured continuously or not. Some dust filters like electrostatic precipitators (EP) are very sensitive on process changes and can have an increased dust emission during transition periods and may not be in compliance during that time.

4. STANDARD TECHNOLOGY (ST) FOR DUST EMISSION REDUCTION

(Technology frequently used in the cement industry)

ST for cement kiln dedusting is the application of bagfilters or electrostatic precipitators. Both are very frequently used and can usually comply with today's dust emission regulations.

Some of the older dedusting technologies like gravel beds or multiclones are still in operation but are not build any more, mainly because they do have difficulties to comply with today's more stringent dust emission regulations.

To reduce the emissions from a pyroprocessing system to a certain controlled level, three basically different methods are available:

- Maintain the existing process while reducing the input of precursor substances into the system
- Modify the existing process (primary reduction measures)
- Maintain the existing process while adding a separate gas cleaning unit for the exhaust gas (secondary reduction measures)

4.1 Reduction of Precursor Substances Input into Kiln System

Dust input can obviously not be reduced because it is the raw material for our product.

4.2 Process Optimization (Primary Reduction Measures)

Modifications of the process can reduce dust emissions from existing dust filters (see below). However, the dust reduction achieved in the process is far below the efficiency of a dust filter. This means that process conditions can support the dedusting equipment to work properly but the final dust emission is always determined by the filter type and its efficiency (secondary measure).

However, there are two exceptions where process changes can even be more efficient than a dust filter. If a grate clinker cooler with conventional vent air dedusting is converted into a ventless system or a satellite clinker cooler is used instead of a grate cooler, the dust emission of the clinker cooler becomes virtually zero.

4.3 Secondary Reduction Measures

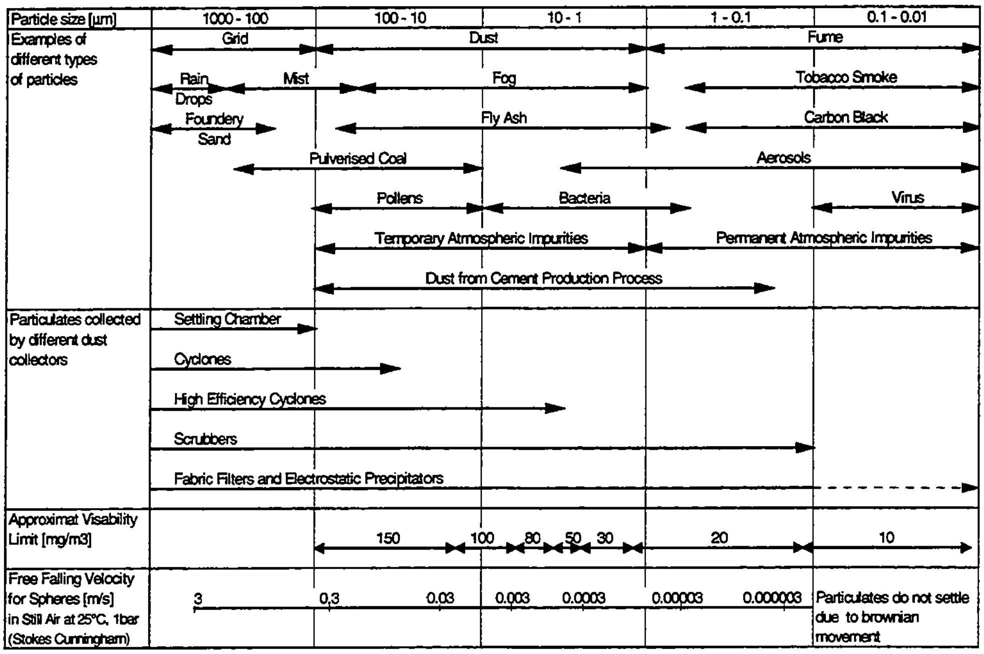
Almost all cement kilns are equipped with dust filters because of economical and ecological reasons. Nowadays, there are basically two different types of dust filters used: bagfilters and electrostatic precipitators. Some time ago also multiclones and gravel bed filters were installed. They are less efficient than modern systems and very often too sensitive on process changes.

5. DUST CHARATERISTICS

The characteristics of dust have a strong influence on the behavior and design of dust filters and on the impact of the dust on its environment. Dust is characterized by

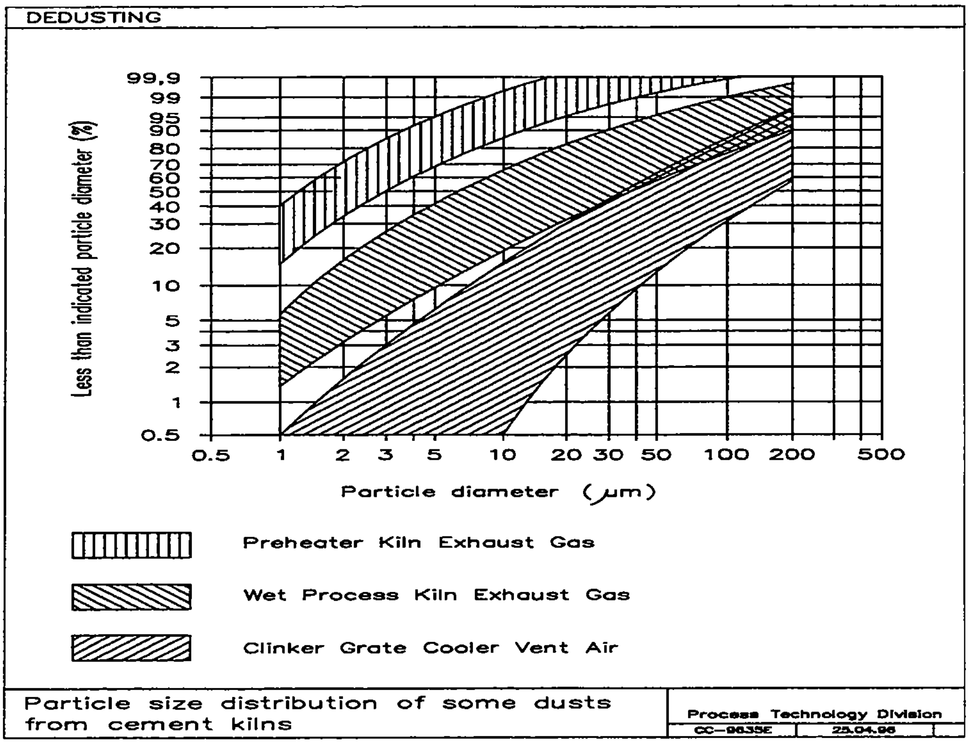
- Size
- Shape
- Hardness
- Chemical composition
- Mineral structure
- Electrical resistivity
- Specific weight
- Angle of repose
- etc.

Fig 1. Comparison of sizes and physical characteristics of various dusts



The character of the dust is defined by its origin and the different treatments like grinding, blending, classifying or burning. Dust from a preheater kiln is much finer than dust from a clinker cooler and because of this more difficult to separate.

Fig. 2: Particle size distribution of some dusts from cement kilns



6. DEDUSTING EFFICIENCY

To describe the performance of a filter or to compare different filter systems the non-dimensional dedusting efficiency η is used. It describes the filter performance independently from the filter load.

$$\eta = 1 - \frac{r}{R} \qquad 1)$$

where:

η = dedusting efficiency

r = clean gas dust content

R = raw gas dust content